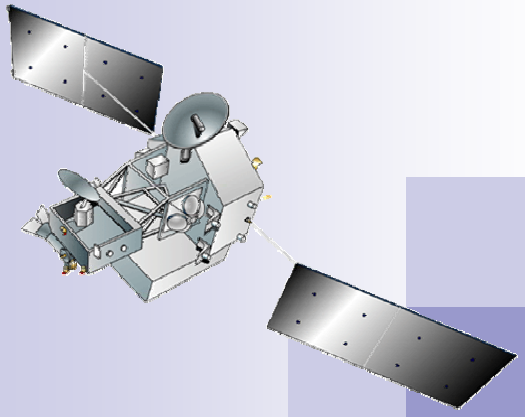

Low-Cost Re-Architecting of NASA's TRMM Mission Control Center

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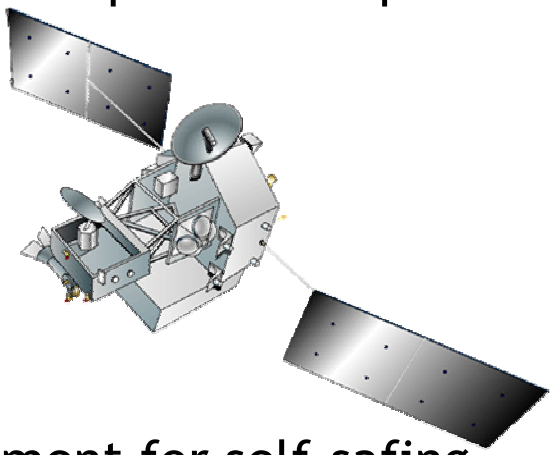
Project Background

- Budgets for NASA space missions typically extend through the end of their original design lifetime
- Scientifically valuable missions which keep operating into an “extended mission phase” are faced with severe operating cost limitations
- TRMM was launched in 1997 with a planned operational life of 3 years - our desire is to extend the mission through 2011
- For TRMM, the NASA Earth Science Mission Operations (ESMO) Office is creating a “pathfinder” system based on GSFC’s plug-and-play message-oriented GMSEC architecture

NASA'S Tropical Rainfall Measuring Mission

- Launched in Nov 1997 with a design lifetime of 3 years
- Low earth orbit: 402 km, 35 degree inclination
- Performs advanced monitoring of rainfall over the tropics/subtropics
- Instruments
  - Precipitation Radar (PR)
  - Visible and Infared Scanner (VIRS)
  - TRMM Microwave Imager (TMI)
  - Clouds and Earth's Radiant Energy System (CERES)
  - Lightning Imager Sensor (LIS)



- Extensive on-board automation and fault management for self-safing
- Robust telemetry stream provides ample fault status messaging

TRMM Re-Engineering Objectives

- Reduce overall spacecraft and data ops costs by 50% in FY 2004
  - *Feb 2004:* Automate to reduce console engineers from 2 to 1 per shift
  - *Oct 2004:* Enable lights out operations for the midnight shift
  - *Nov 2004:* Reduce H/W maint. costs by replacing outdated equipment
- Implement, deploy and begin use of the new system without impacting ongoing operations
- Demonstrate the GMSEC architecture as a proof of concept to use as the basis for automating other NASA missions (Terra, Aqua, Aura)
- Deploy an operational system in 15 months with less than $2M

Technical Approach

- Employ a phased approach to meet immediate and long term budgetary concerns
- Add new tools to old system to enable immediate staff reduction (problem recognition and user paging)
- Replace front-end processor
  - Conversion from Serial to Internet Protocol (IP) eliminates outdated H/W
- Replace legacy telemetry and command system
  - Will now use Raytheon's Eclipse instead of in-house system
  - Standardizes Earth Science T&C systems to reduce H/W and S/W maintenance costs
- Integrate ground components into GMSEC architecture to allow use of automation and monitoring tools
- Introduce simple ground automation
  - Routine pass activities
  - String failovers
- Allow for future expanded use of automation tools

Automation Philosophies

- Current NASA Goddard missions use custom automation software
  - ***GOTS Expert Systems*** are composed of fully integrated automation components, such as paging, automatic scheduling, analysis, fault isolation and recovery
  - ***Customized Scripting Tools*** developed in-house for mission unique automation
- TRMM will provide user configurable automation toolset
  - Contemporary COTS provide more automation eliminating the need for complex, integrated automation tools
  - This approach facilitates “plug-and-play” components to support evolving technology
    - Standard interface enables an infrastructure that is independent of its components

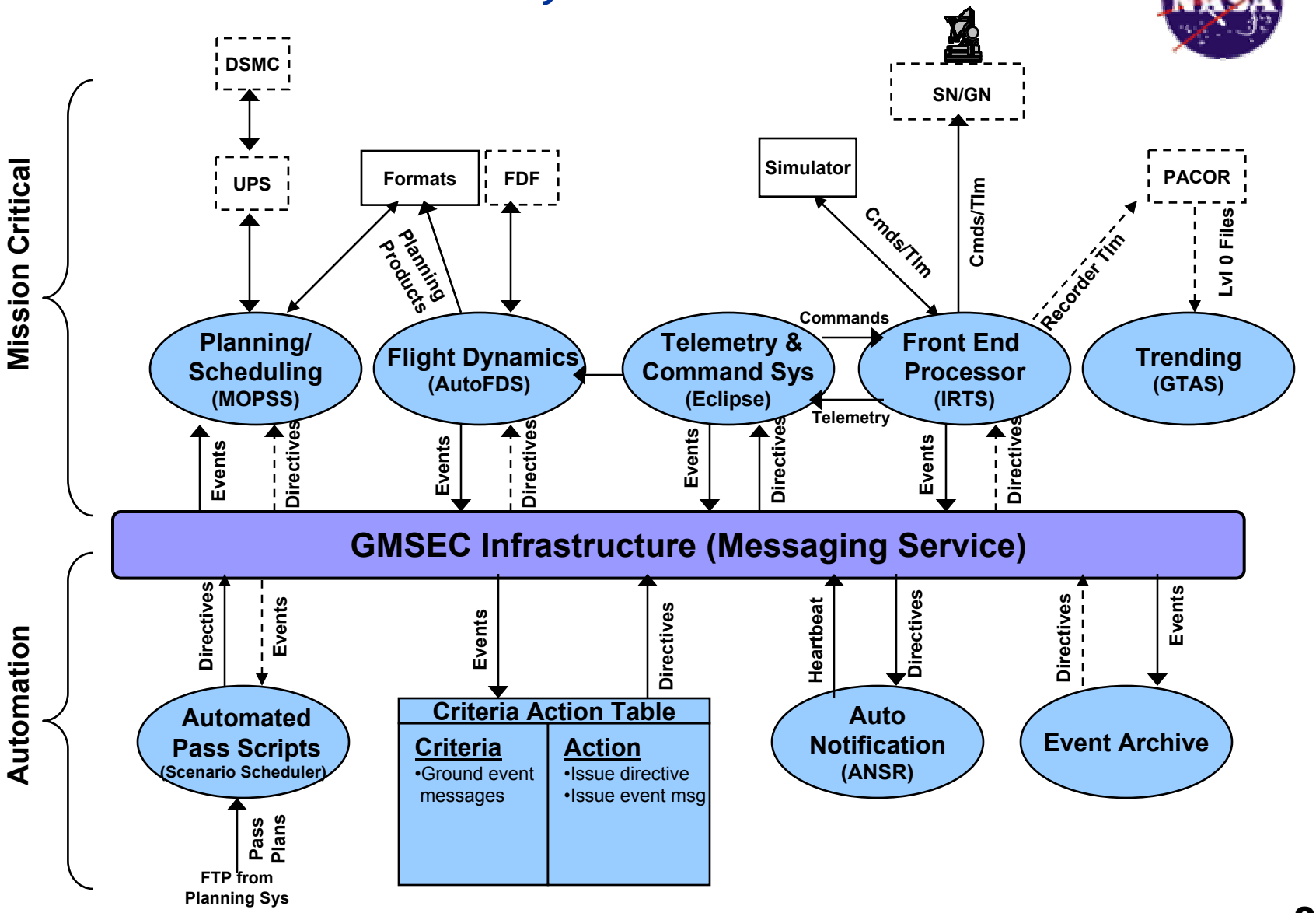
TRMM Automation Approach

- Implement two automation approaches: event-driven and time-driven
  - ***Event-driven*** based on automatic responses to ground generated event messages using rules and actions
    - Sends directive to paging system for text paging engineers when spacecraft limits violated and critical ground events occur
    - Sends directive to trigger automatic ground reconfigurations
  - ***Time-driven*** based on automatic execution of pass activities through static and dynamic pass plans
    - Automate spacecraft real-time activities during night shift
    - Configure ground system pre-pass, realtime support, and post-pass

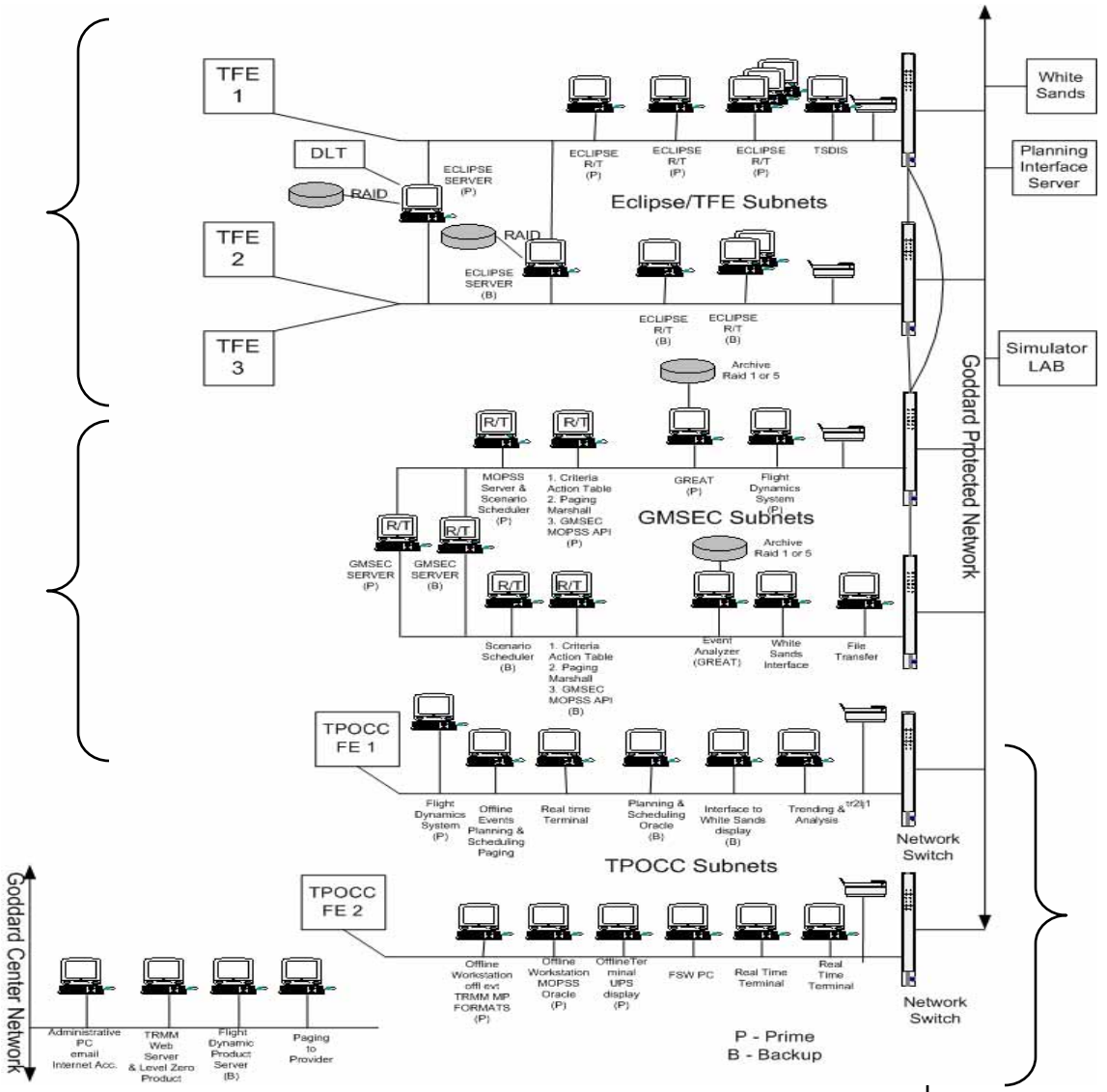
GMSEC Architecture Integration

- Development and testing approach
  - Components to modify their software to support standard interface and message formats
  - Establish Control Center test facility to test ground component communication on the software bus
- Middleware software bus
  - TIBCO Smart Sockets offers guaranteed delivery of event messages and directives
  - FY 2004: Implement event messages, directives, and heartbeat messages
  - FY 2005: Integrate further ground system automation, as well as transfer telemetry and products via the bus

GMSEC System Architecture



Final Architectural Diagram



Challenges

- Major challenge has been to implement an operational system in 14 months without exceeding budget
- Extensive Control Center changes requires a continuous re-assessment of risk
- Re-engineering an on-orbit ground system adds complexity to testing and rehosting new systems
- Critical support team was difficult to capture due to transition of mission support contract
- Lack of documentation causes code reverse engineering, driving costs higher than anticipated

Conclusions

- Although challenging, our goals are achievable
- The TRMM re-architecting effort offers ground-breaking technological advances for NASA missions
- Pioneering this innovative approach will enable its reuse for other NASA missions
- Current NASA Goddard mission automation paradigm will evolve to a message-oriented infrastructure with simple automation tools
  - Systems may easily evolve with a “plug and play” architecture
  - Contemporary COTs offer sophisticated automation, eliminating the need for complex tools